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Alternative Methods for Proposed Explosive Demolition of Large, Obsolete POL Storage Tanks, Fort Leonard Wood, Missouri

by James K. Ingram, James B. Cheek
Structures Laboratory

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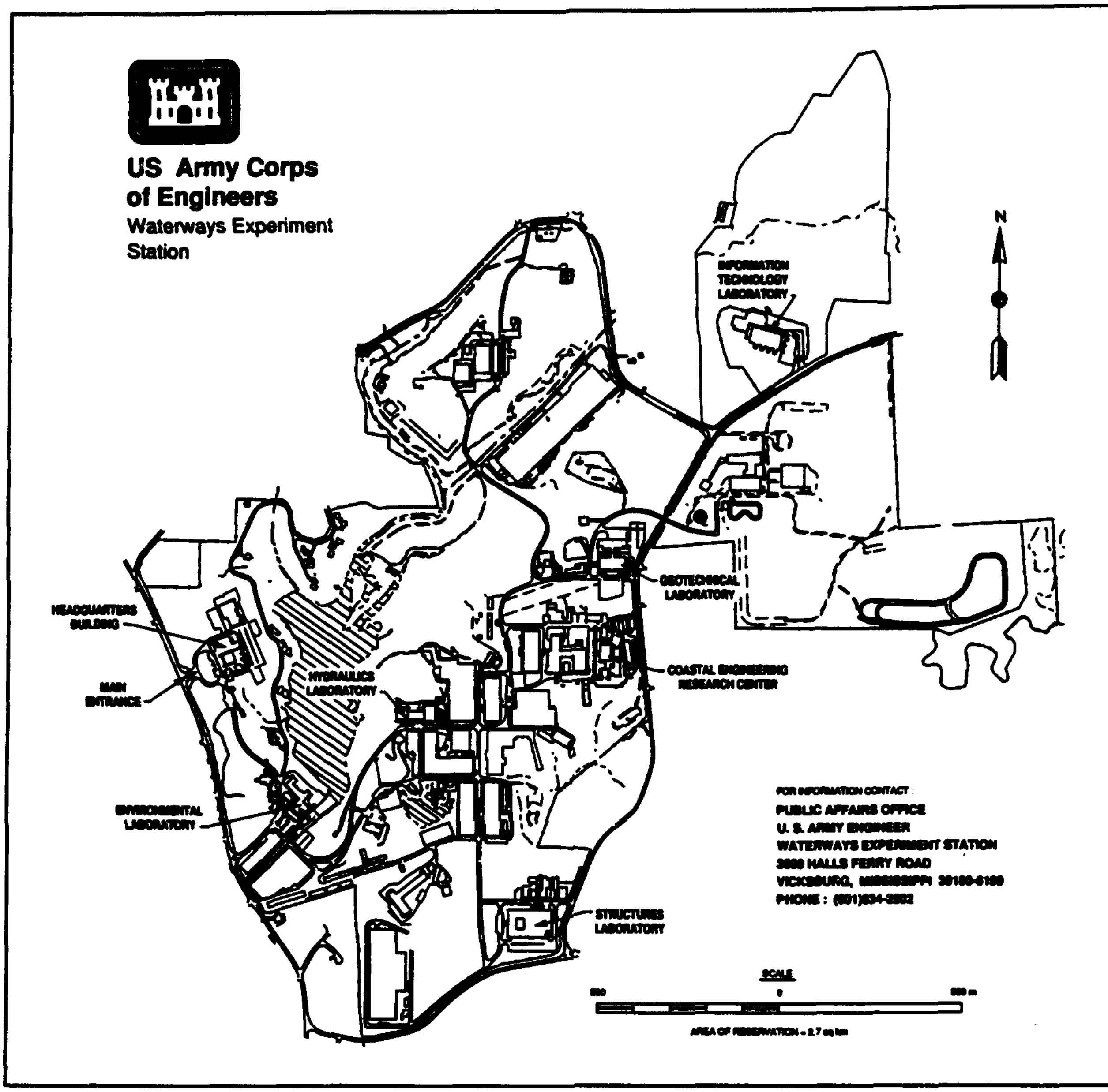

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Preface

Ft. Leonard Wood, Missouri, personnel contacted the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for an analysis of explosive removal of three very large obsolete petroleum, oil, and lubricant (POL) storage tanks (up to 200,000-gal capacity). The criteria for explosive destruction were safety, full destruction to ground level, and minimum corollary hazards to nearby civilian population. Funding for this study was provided by the Department of the Army to the Structures Laboratory (SL), WES.

This study was conducted by Mr. James K. Ingram, Explosion Effects Division (EED), and Mr. James B. Cheek, Structural Mechanics Division (SMD); both Divisions are part of SL, WES. During this investigation, Mr. Landon K. Davis was Chief, EED; Dr. Jimmy P. Balsara was Chief, SMD; and Mr. Bryant Mather was Director, SL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
gallons	4.404884	litres
inches	25.40	millimetres
feet	0.3048	metres
nautical miles per hour (knots) = 1.136 standard miles per hour	1.852	kilometres per hour
pounds (mass)	0.4536	kilograms
pounds (force) per square inch (psi)	0.006895	megapascals

1 Introduction

Background

The 135th Engineer Brigade, U.S. Army, Ft. Leonard Wood, MO, was tasked with explosive ordnance demolition (EOD) of three very large obsolete petroleum, oil, and lubricant (POL) storage tanks. Two of these tanks have a 100,000 gallon capacity and one has a 200,000 gallon capacity. The tanks are conventional right circular cylinders, fabricated with standard steel plate construction (Figure 1 and Reference 1). The primary concerns are to be able to bring the tanks down to ground level with minimum effort, expense, safety, and minimum corollary hazards. The method proposed by the EOD personnel at Ft. Leonard Wood would use discrete blocks of small explosive charges on the sides and tops of the tanks, followed by an internal detonation of a "dust" explosive (Reference 2). The Explosion Effects Division (SE), Structures Laboratory, of the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, was contacted by CPT Shawn Hunter and asked to review the proposed technique and to provide an alternate approach or approaches if we disagree with the plan of Ft. Leonard Wood personnel.

Objective

The objective of this study was to assist personnel at Ft. Leonard Wood, MO, in developing an EOD plan for destruction of the POL tanks that is both effective and free of significant hazards.

Scope

The scope of this report is limited to recommendations based on past experience and literature searches. Experimental evaluation of the techniques proposed in this report was not conducted.

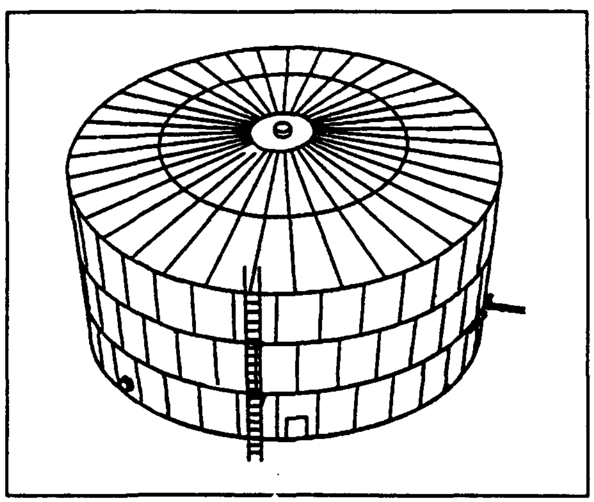

Figure 1. Typical steel plate construction POL storage tank

2 Approach

Assessment

A WES analysis team was assembled to review the Ft. Leonard Wood proposal. The team consisted of Messrs. J. K. Ingram, G. Rubin de la Borbolla, and G. W. McMahon of the WES Explosion Effects Division; and Mr. J. B. Cheek of the Structural Mechanics Division. The proposed methodology was reviewed along with appropriate background research and team experience. The team assessment resulted in modifications to the original proposals which should produce safer and more reliable results.

Analysis of Explosive Method

Several potential problems were identified in the test plan provided by Ft. Leonard Wood. Neither of the two proposed approaches (Reference 1, Paragraphs 2 and 3) was determined to be totally acceptable by itself.

Method A proposed the use of a "dust" explosive detonated inside the storage tanks. An erroneous assumption is stated in Reference 1, Paragraph 3: "Presumably, the dust initiator causes an implosion effect rather than an explosion." In actuality, only an explosion can occur. Weakening of the structure by the initial detonation, followed by rapid venting of the explosive gases to the outside atmosphere and subsequent reduced internal pressure behind the blast wave, allows normal atmospheric pressure to act on the exterior of the structure which now contains a reduced internal pressure. This causes the structure to fall inward (provided the proper structural conditions are present), thus giving the appearance of an implosion.

The "dust" explosive, as described in FM 5-25 (Reference 2), Pages 4-79 and C-3, is indicated to be a field expedient under make-do combat conditions. The instruction to prepare the required powdered primary explosive from solid form by placing TNT in a canvas bag and crushing it is definitely NOT recommended for other than combat scenarios. This is an extremely hazardous operation and should be avoided. Home-made explosives such as these have performances that are, at best, poorly characterized and

highly unrepeatable. Prediction of the blast effects produced by the "dust" explosive will be unreliable. This is of particular concern, considering the relatively close habitation in the vicinity of the storage tanks (approximately one-half mile away).

Method B proposed placing a number of two-pound explosive charges at intervals around the outside circumference of the storage tanks. If a sufficient number of the small charges are placed on the tanks, and if they are placed at the proper locations, the tanks can be brought down effectively. However, if insufficient or improperly placed charges are used, the result will be a weakened, but still standing, structure that will present a real danger to personnel required to disassemble it.

Recommended Methodology

General

Several alternative methods of explosive demolition are recommended for consideration instead of either Method A or B. All methods suggested by WES recommend an internal charge to minimize the total quantity of explosive required. Several candidate explosives can be used; the most critical (driving) requirement is the generation of an internal pressure of at least 100 psi. The high-explosive (HE) charge weight requirements will add conservatism (and higher confidence) to the desired destruction, but the upper limit of pressure will be determined by both the explosive selected (fuel-air explosives (FAE) are limited to less than 400 psi), and range-safety considerations (i.e., excessive breakup of the structures with resulting long-distance fragment trajectories, and excessive airblast pressures in the vicinity of nearby habitation).

Alternate Method A

Alternate Method A uses well-characterized, known-performance explosives, which should assure the desired demolition on the first attempt. Beam-cutting charges should be used to sever all primary support beams (if any) within the storage tanks. Instructions for this operation can be found in FM 5-25 (Reference 2), Pages 3-9 through 3-17, and 4-72. Vertical array (line) charges should be placed along each quadrant of the tanks (and preferably every 60 degrees around the circumference as shown in Figure 2). The line charges can be fabricated using standard blocks of Detasheet attached continuously or at intervals along a Primacord stringer (continuous explosive is preferred). The Primacord stringer is optional and would be used primarily for initial detonation of the line charge and to ensure continuous detonation of the discrete explosive components. Detonation of these line charges will effectively split the sidewalls of the tanks and weaken the roof support (see Reference 2, Pages 3-13 and 3-14).

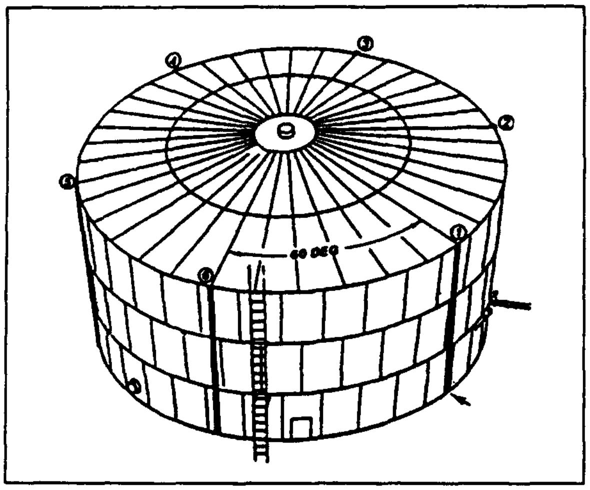

Figure 2. Suggested placement with "line" cutting charges

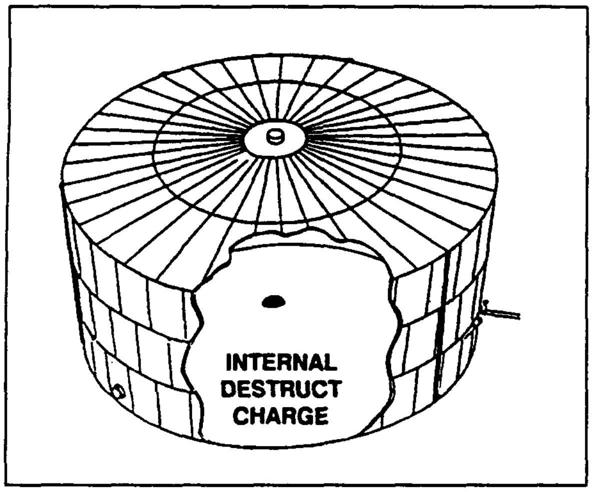

Figure 3. Interior charge placement

For the two 100,000 gallon storage tanks, a single Navy SLUFAE warhead (an 85-pound FAE round) or two Navy BLU-73/B warheads (33.5-pound FAE round) are recommended for the interior destruct charge (Figure 3), if readily available. For the larger 200,000 gallon tank, two SLUFAE or four BLU-73/B warheads are recommended. Detonation of these FAE rounds should produce an internal pressure of about 300 psi, which should be more than sufficient to cause the tanks to collapse. The FAE charges should be placed in the center of the tanks, preferably at a slightly elevated position (3 to 10 ft high) above the floor to enhance the dispersal of the explosive aerosol. Additional small C-4 or Detasheet explosive charges can be placed inside the tanks near the base of the footings to force the base skirt outward.

The explosives can be detonated simultaneously if the total explosive weight falls within the allowable limits established for the specific site, and the corollary airblast effects are within acceptable levels. If the total explosive weight exceeds allowable limits, the explosives can be sequentially detonated to control the explosively-generated peak pressures and impulses. The recommended detonation sequence is given in Table 1.

Table 1
Recommended Detonation Sequence

Step	Operation
1	Detonate beam cutting charges (if used)
2	Detonate vertical skirt cutting line charges
3	Detonate footing cutting charges (if used)
4	Detonate interior explosive charge(s)

Alternate Method B

Alternate Method B considers the use of locally available material for the interior FAE charge. A mixture of propane (C_3H_8) and air at a 7.5 percent by weight mix ratio (Reference 4) can be substituted for the Navy FAE ordnance rounds suggested in Method A. Calculations indicate a propane weight of 18.2 pounds should be used for the 100,000-gallon tanks, and 38 pounds for the 200,000-gallon tank. This fuel-air mixture should be IGNITED, not detonated. Ignition and subsequent burning of the gas mixture should produce an effective internal tank pressure of approximately 100 psi. Detonation of the gas mixture will drive the internal pressures above 300 psi. The increased pressure from detonating the mixture would be allowable (and, in fact, may be unpreventable), and would cause only slightly higher overpressures at distance. While this method is both inexpensive and effective, it is potentially one of the most hazardous. Leaks pose danger to operating personnel, particularly if delays are encountered between fill time and ignition time due to shot delays, weather, etc., and the gas has sufficient time to leak into undesirable areas. Normal safety regulations usually preclude use of large-volume gas systems unless the tanks are verified to be sealed and leak free.

Alternate Method C

Alternate Method C will substitute a lumped charge of high explosive (HE) for the FAE suggested in Alternate Methods A and B, above. The HE charge can be constituted from stacked blocks of C-4, Detasheet, or ammonium nitrate-fuel oil (ANFO). ANFO is only 5/6 as efficient at producing airblast as HE, but produces more impulse making it an ideal candidate explosive for the interior charge.

ANFO can be made easily by purchasing locally available ammonium nitrate fertilizer and adding approximately 5 percent (by weight) fuel oil. The material should be thoroughly mixed and allowed to stand at least overnight in sealed plastic bags (the material is highly hygroscopic and moisture entrainment degrades the explosive efficiency). The ANFO must be initiated with a primary booster of C-4 or equivalent explosive. Premixed and bagged ANFO can be obtained form local commercial suppliers.

Collateral Effects

Fragmentation and hazardous long-range ejecta are not expected to present a significant problem if the structures are demolished as suggested. Figure 4 is a parametric plot of airblast overpressures versus ground range from the explosives. This figure can be used to determine a range of charge weights and resultant pressures, if higher internal detonation pressures are desired to ensure a measure of conservatism. The maximum airblast pressure levels produced by the explosions should present few nuisance complaints, assuming habitation is no closer than one-half mile from the detonation site. A

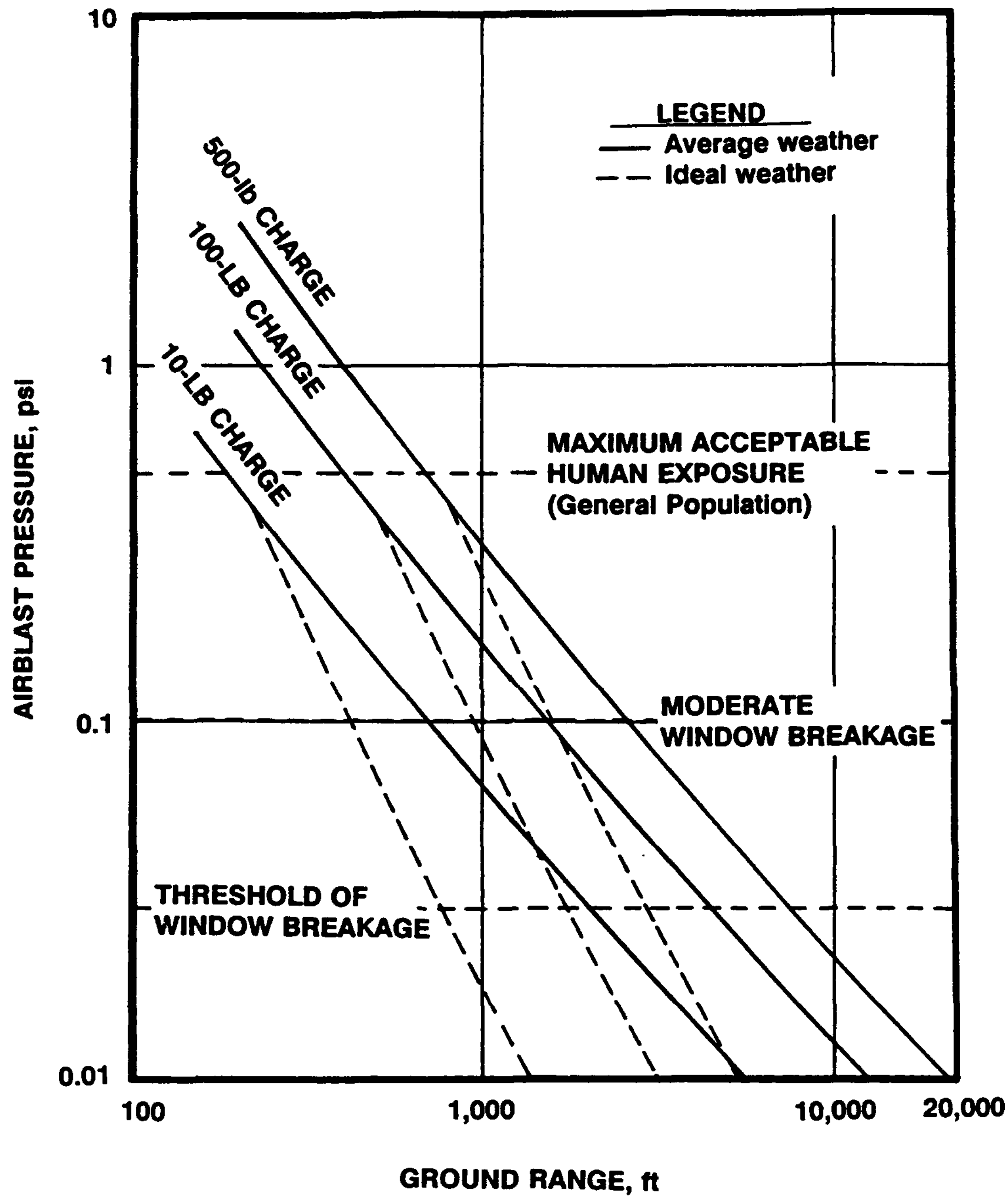

Figure 4. Blast pressure versus range curves for 10-, 100-, and 500-lb charge weights

conservative blast pressure level of 0.03 psi normally is used as the safety threshold for large plate-glass windows, such as store fronts, etc., and 0.1 psi for small, single-pane windows normally found in family dwellings.

Assuming the use of FAE for the primary explosive charge, with a maximum source pressure on the order of 300 to 350 psi (typical for all gas-air detonations), the 0.03-psi radius contour will extend to an expected distance of 3,000 feet, and the 0.1-psi contour will extend to a distance of 1,600 feet (References 5 and 6). The 0.03- and 0.1-psi overpressure contours are based on the assumption that the actual volume of the FAE produced in the large tank will be the same as that produced in free air. The equivalent charge weight then was estimated by calculating the TNT charge required to produce a spherical gas volume equal to that of the large tank, and whose surface peak pressure at that instant of equal volume is 300 psi. This initial estimate was used to drive the far-field blast overpressure versus range calculation. The ranges for 0.03 and 0.1 psi are based on detonation under ideal weather conditions. Under probable average weather conditions, the ranges would extend to 7,200 feet and 2,600 feet, respectively. The sequential detonation of the vertical line charges, base charges, and, finally, the interior charge at intervals not less than 8 milliseconds apart will assure that the safe distances listed above are valid. Simultaneous detonation of all the charges will increase the safe distance requirements, and is not recommended.

It is important to consider the effects of temperature inversions which may be present in the local atmosphere and the wind velocity and direction at shot time, as these parameters can seriously modify the far-field blast effects (Reference 6). Under certain weather conditions (i.e., atmospheric temperature inversion, high-velocity winds blowing in the direction of sensitive areas such as inhabited buildings, fragile structures, etc.), the actual peak pressures may be increased by as much as seven times those occurring under ideal weather conditions.

Based on the foregoing considerations, detonations should be conducted, if at all possible, under clear sky conditions, low velocity surface winds (less than 8 knots), moderate to low upper level winds, and associated wind vectors away from sensitive areas. Consultation with the local military and civilian aviation weather advisory center is recommended before committing to a detonation. An on-site meteorology station would be of greater benefit, if such equipment is available. Range safety-distance predictions are given in Table 2 and Figure 4. Blast enhancement due to non-ideal or "average" weather (longer distance airblast propagation) and reduced blast pressure at distance for "ideal" weather (shorter distance airblast propagation) are illustrated.

It should be noted that the predicted pressure for a given range may vary from shot to shot by as much as 50 percent, depending on specific atmospheric conditions at the time of each detonation. This added uncertainty should be considered for assessment of collateral effects which must be minimized. Charge weights shown in Figure 4 are in terms of TNT equivalence,

which is used as the HE standard reference explosive. Because the peak-blast pressure varies with range as the cube root of the charge weight, minor differences in explosive weight (i.e., total amount of explosive detonated at a given time) or charge type do not significantly affect the far-field blast pressures. Because of this relationship, the provided curves are applicable to most conventional explosive types.

Table 2
Range-Safety Pressure-Distance Values for 100- and 500-pound Explosive Charges

Consideration	Pressure Threshold, psi	Explosive Weight, lb	Range From Explosion, ft — Weather	
			Ideal	Avg.
Threshold of Window Breakage	0.03	100 500	1,560 2,900	4,300 7,200
Moderate Window Breakage	0.10	100 500	870 1,800	1,800 2,800
Maximum Human Exposure[1]	0.50	100 500	400 690	400 690

[1] Unprotected, general human population.

3 Conclusions and Recommendations

All of the recommended alternative explosive demolition methodologies suggested in this report should allow safe, efficient collapse and breakup of the large obsolete storage tanks. Alternate Method C (lumped charge of standard solid explosive, coupled with beam and seam cutting linear charges) is the preferred method from both EOD safety and materials availability standpoints.

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13. ABSTRACT *(Maximum 200 words)*

A desk study was undertaken to assess explosion demolition methodologies that would allow Army Explosive Ordinance Demolition (EOD) engineer teams assigned to Ft. Leonard Wood to safely and effectively demolish to ground level three very large metal POL (petroleum, oil, and lubricant) storage tanks. These tanks have outlived their usefulness and are scheduled for removal by the most rapid and cost effective method. An analysis by Ft. Leonard Wood determined explosive demolition to be the method of choice. A primary concern was possible corollary damage to nearby military and civilian housing and occupants.

This study investigated several explosive sources and methodologies and provided predictions of corollary damage effects versus distance from the charge to be expected for explosive charge weights ranging from 10 to 500 lb. Prediction curves were developed for both ideal and average weather conditions.

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